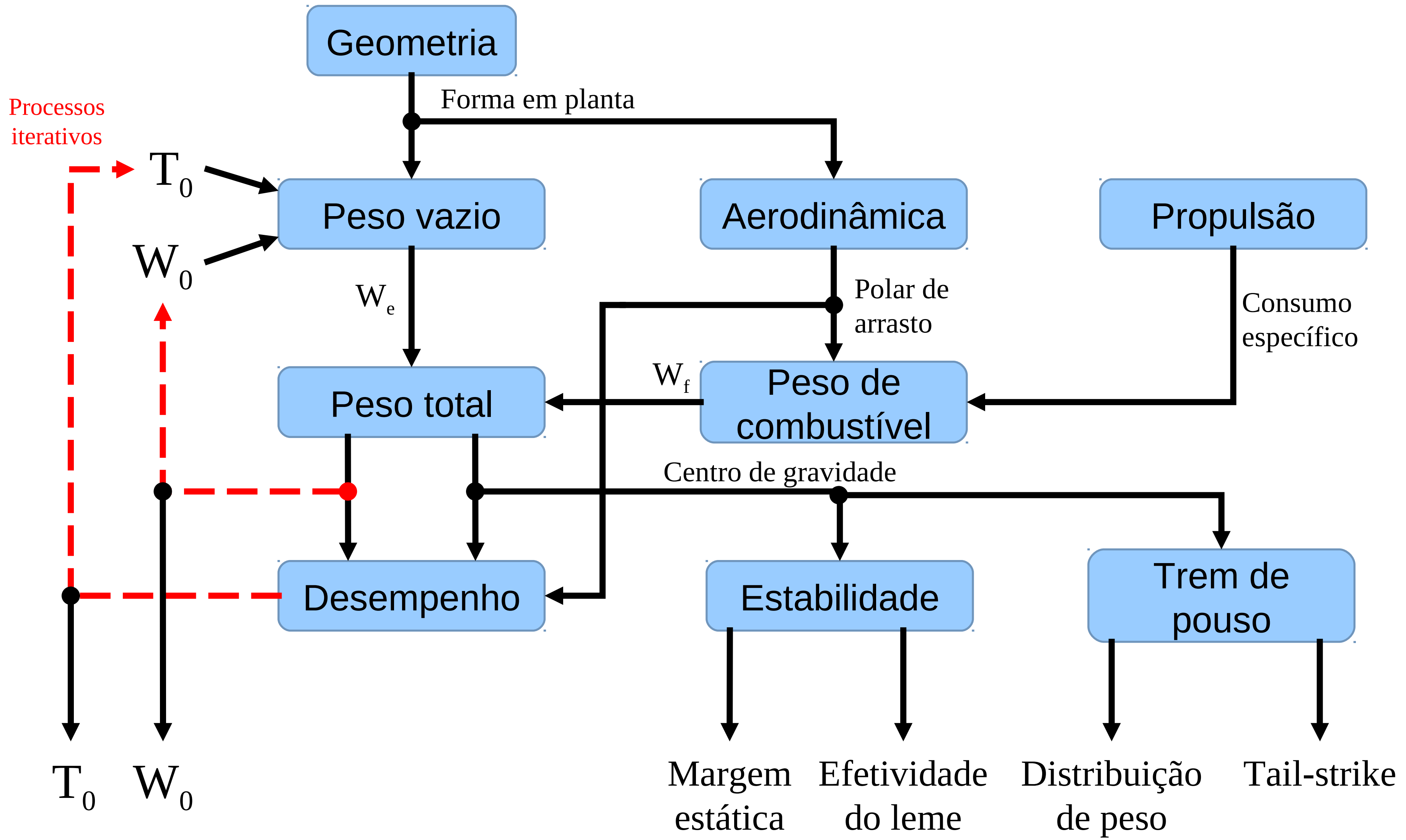
Instituto Tecnológico de Aeronáutica
Mestrado Profissional em Engenharia Aeronáutica

AP-701
Fundamentos do Projeto de Aeronaves

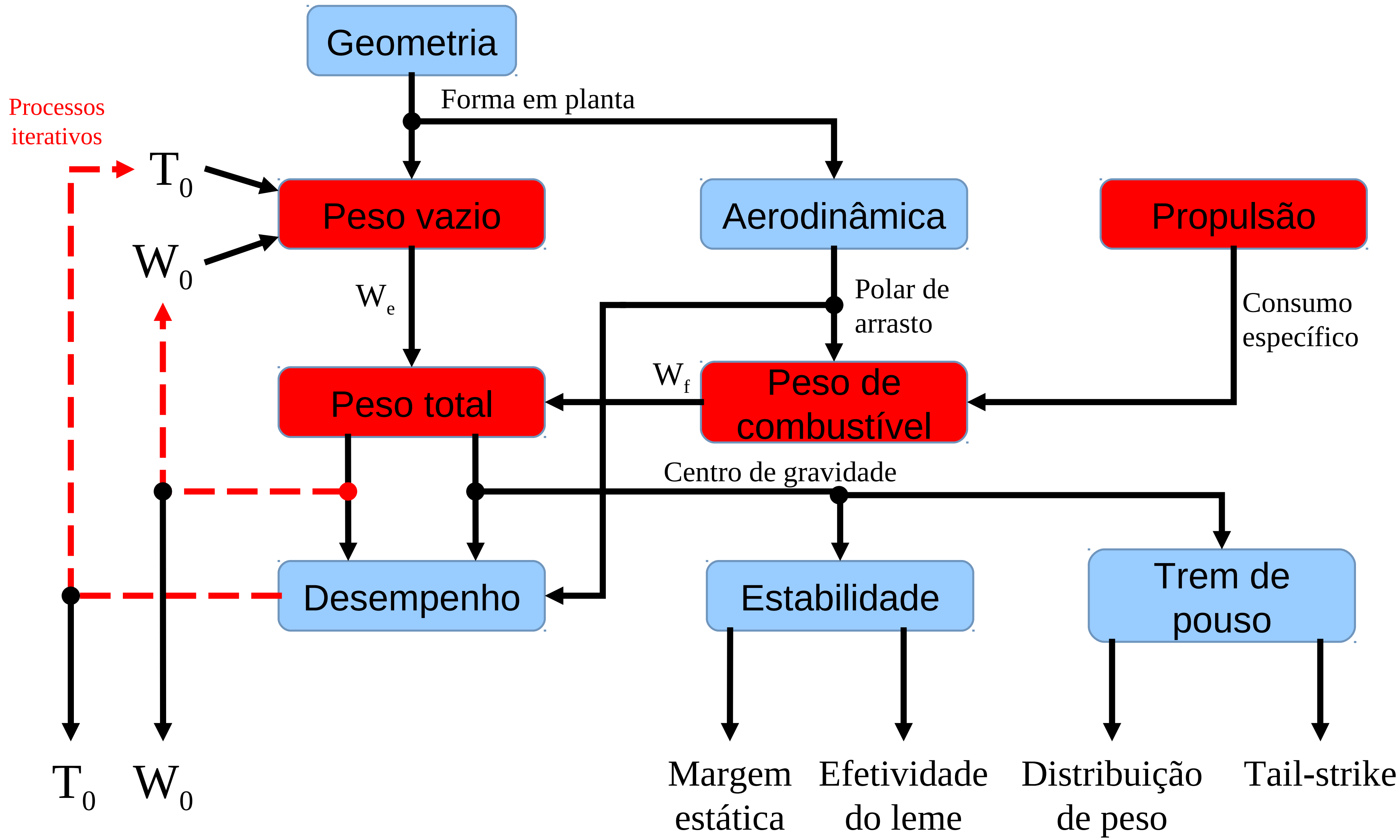
Aula 4 – Propulsão; Pesos

Cap. Ney Sêcco

Fluxo de análise



Fluxo de análise



Roteiro

- Propulsão
- Peso

Roteiro

- Propulsão

- Peso

The aircraft engine has interfaces with several other systems and a decisive impact over the vehicle performance

Maximum speed

Noise & Emissions

Service ceiling

Fuel consumption

Yawing moment

Reliability

Pneumatic system

Maintenance

Power generation

Bird ingestion

Engine mount

Blade failure

www.3dhorse.com

Thrust is generated by accelerating the air around the airplane

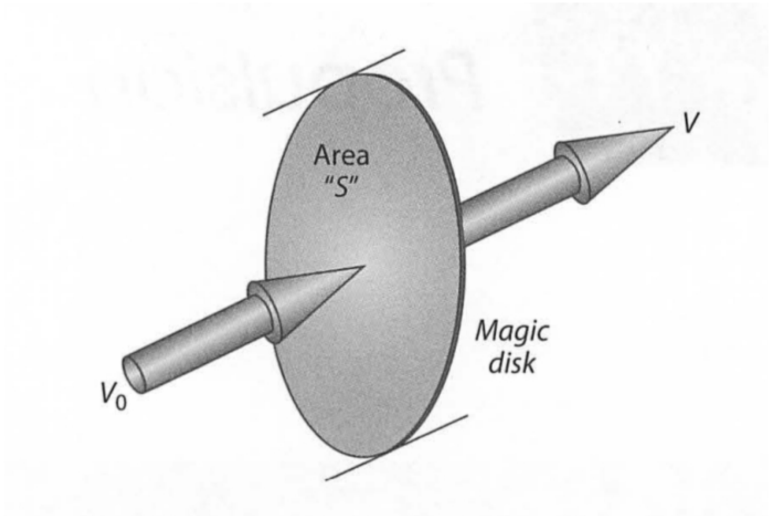


Fig. 13.1 Simplified thrust analysis model.

Thrust

$$T = \dot{m}(V - V_0)$$

Propulsive efficiency

$$\eta = \frac{2}{1 + \frac{V}{V_0}}$$

Thrust is generated by accelerating the air around the airplane

Thrust

$$T = \dot{m}(V - V_0)$$

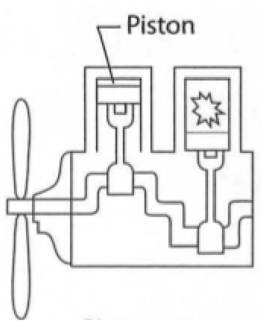
Propulsive efficiency

$$\eta = \frac{2}{1 + \frac{V}{V_0}}$$

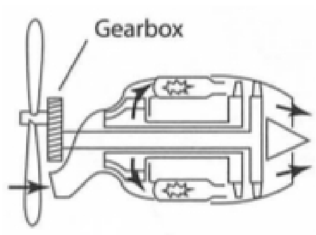
- Changes in velocity of the accelerated air are a waste of energy
- It is more efficient to accelerate a large mass by a small velocity change
- But this is not always possible (e.g. high tip speeds)

Os motores podem ser divididos em dois grupos

Motores a hélice

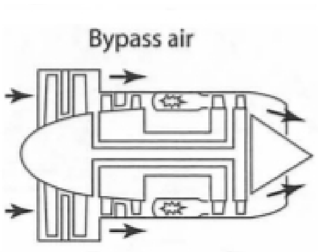


Pistão

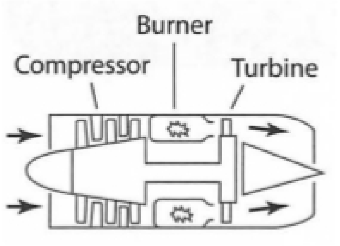


Turbohélice

Motores a jato



Turbofan

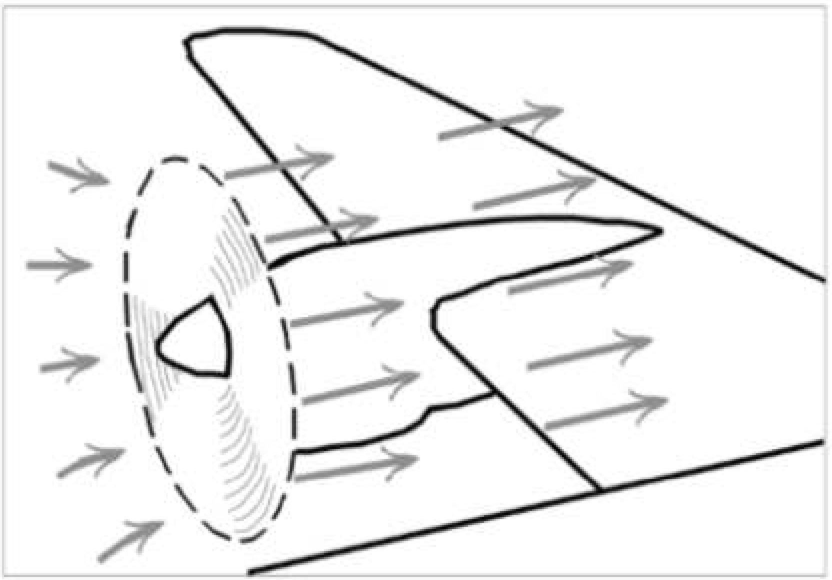


Turbojato

Raymer

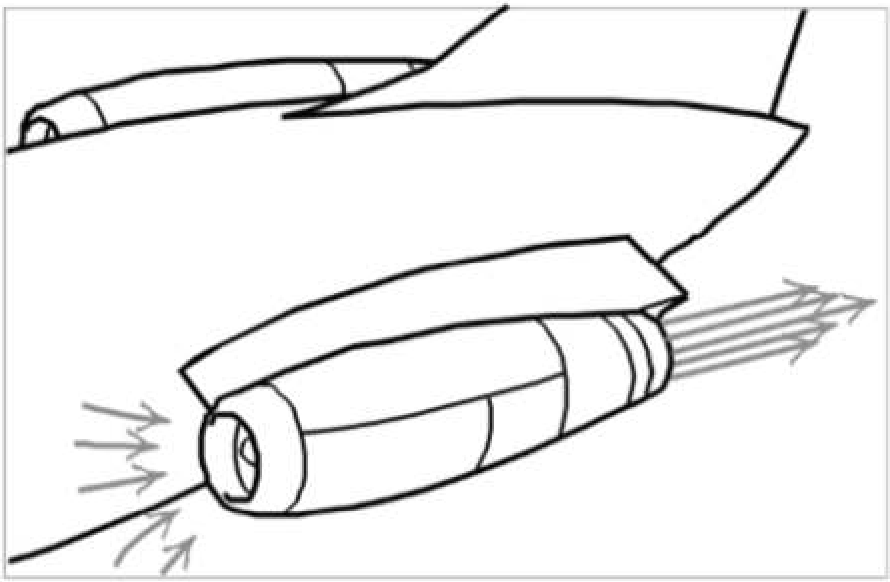
Os motores podem ser divididos em dois grupos

Motores a hélice



Small velocity increase on a large air mass

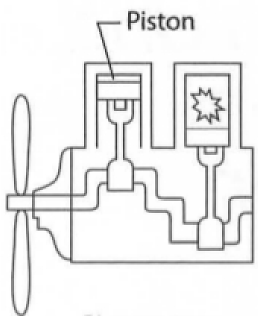
Motores a jato



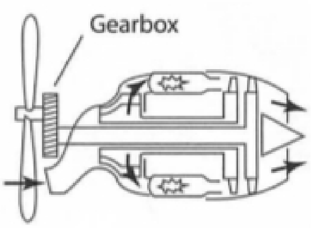
Large velocity increase on a small air mass

Os motores podem ser divididos em dois grupos

Motores a hélice



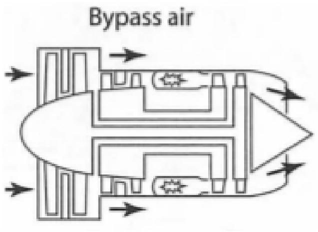
Pistão



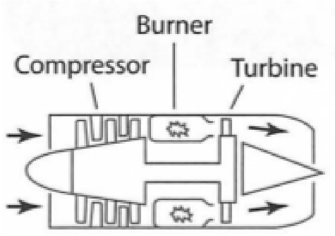
Turbohélice

- Limitação de velocidade por velocidade na ponta da pá
- São dimensionados com base na potência
- Fabricante da aeronave precisa definir a hélice, caixa de redução e nacelle

Motores a jato



Turbofan



Turbojato

- Menor eficiência em baixas velocidades
- São dimensionados com base na tração
- Fabricante da aeronave precisa definir a nacelle

Raymer

Flight speed drives engine selection

Raymer

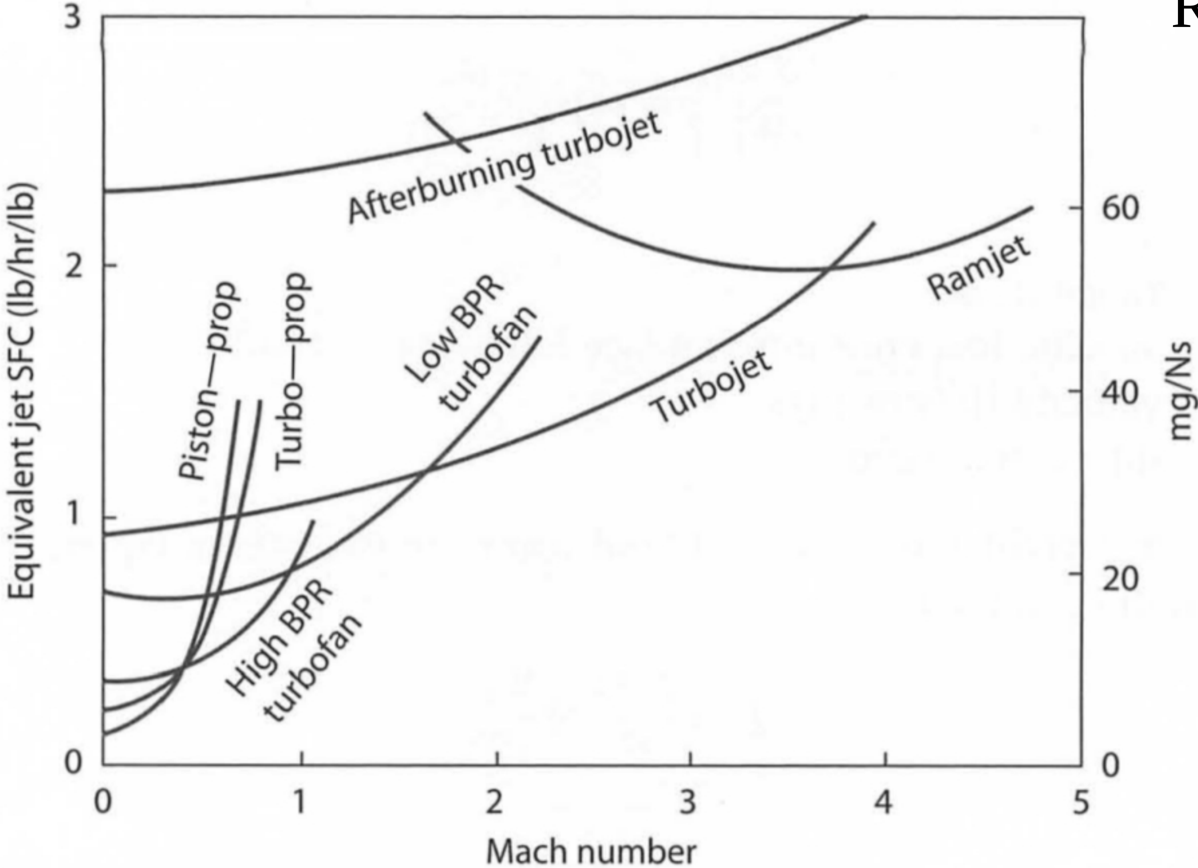
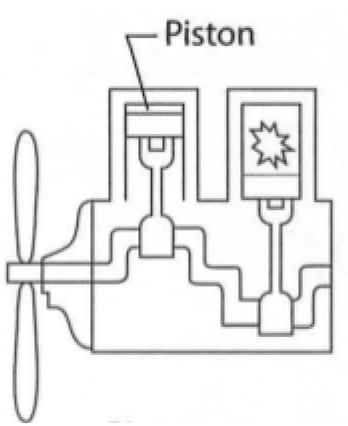
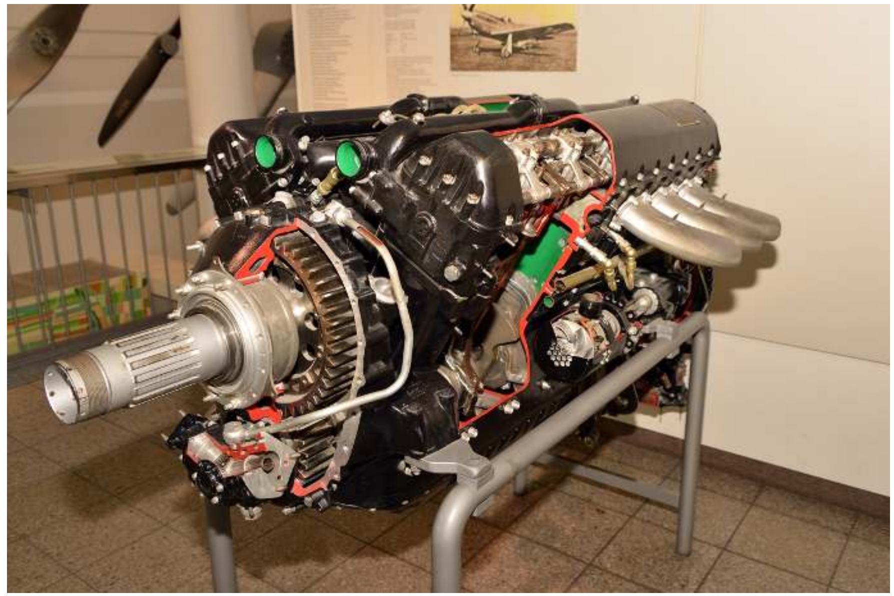


Fig. 3.3 Specific fuel consumption trends (at typical cruise altitudes).

Piston engines are used since the dawn of aviation

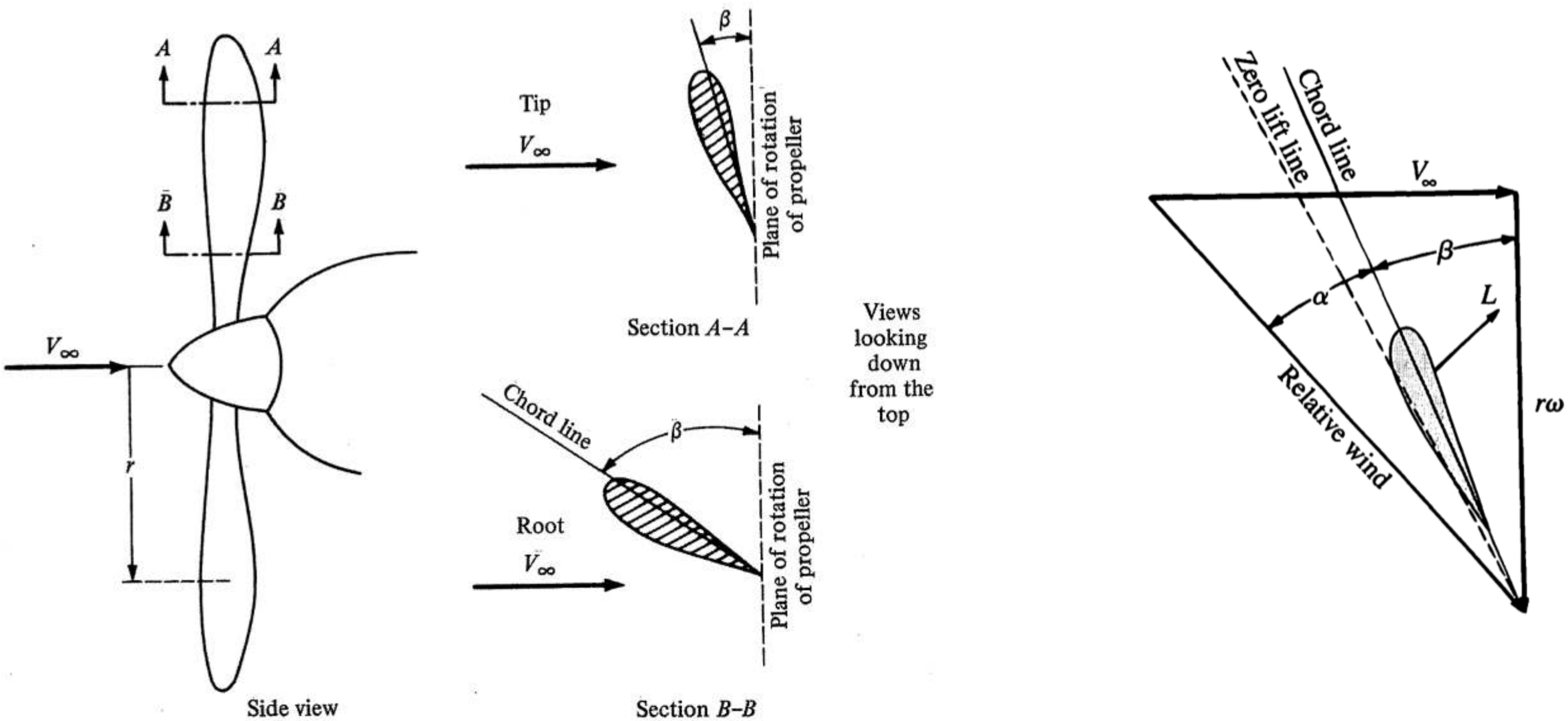




- V-1650 Merlin
- 12 cyclinder in “V”
- Powered the P-51

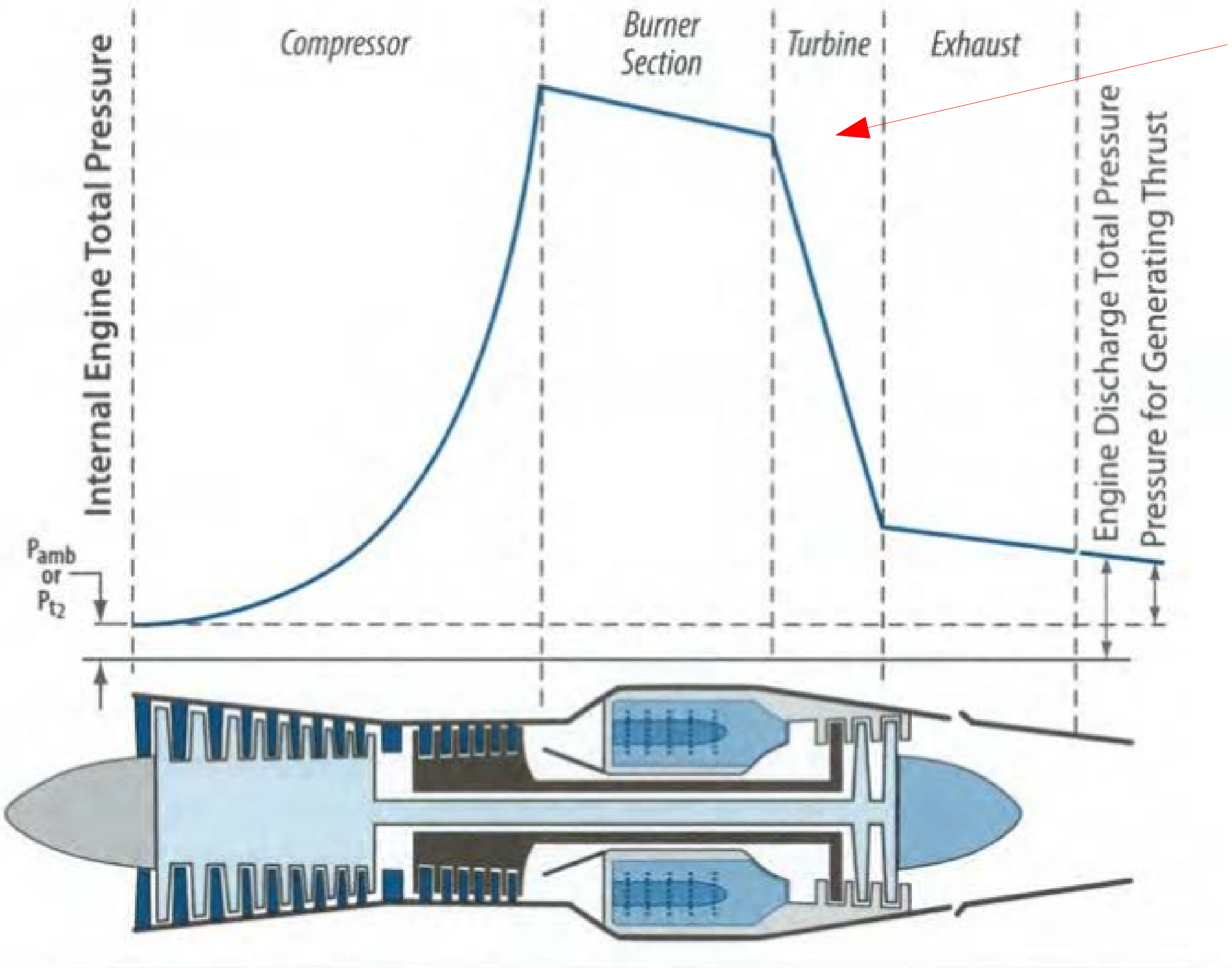
- Efficient and cheap (appropriate for general aviation)
- Heavy and noisy
- Limited by sonic speed at propeller tips
- Designed to provide a given power

The propeller design is an important factor for piston and turboprop engines



- Higher diameter improves efficiency at low speeds
- Higher pitch improves efficiency at high speeds (but blade stalls at low speeds)
- There are variable pitch propellers
- We assume that propellers usually have 80% of propulsive efficiency at cruise

Turbojet is more efficient for low supersonic speeds

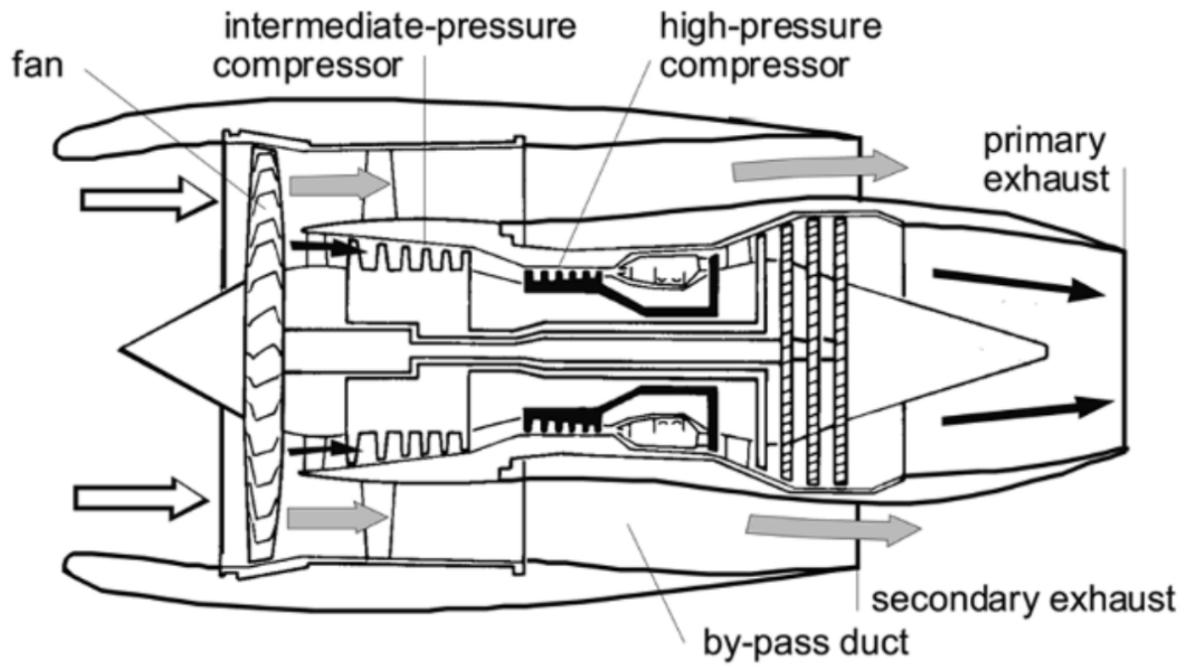


Turbine temperature is a limiting factor

Nicolai

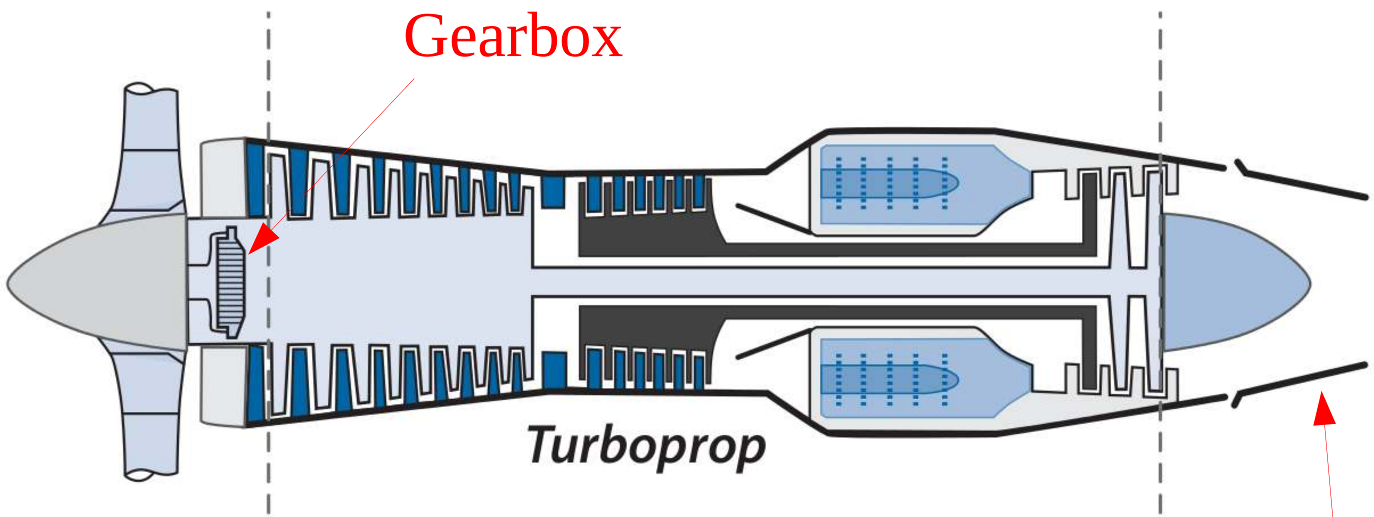
- Higher velocity variation with smaller mass flow
- Avoids tip speed problems

Turbofan



- Increase mass flow by adding a fan
- Cold air bypasses the gas generator
- Higher bypass ratios are more efficient, but lead to higher diameters
- Inlet must reduce flow speed to Mach 0.4-0.5 to avoid supersonic speeds at the blade tips
- Flow deceleration reduces its efficiency for high Mach numbers

Turboprop

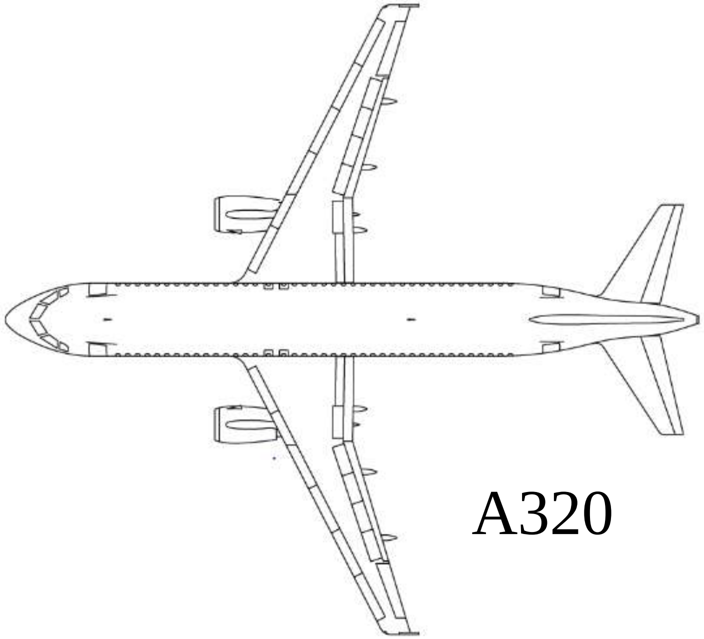


5% of thrust from jet exhaust

- Gas generator with an attached propeller
- Gas generator can work at a fixed power
- When compared to piston engines, turboprops:
  - Have higher fuel consumption
  - Are more expensive
  - Quieter
  - More reliable

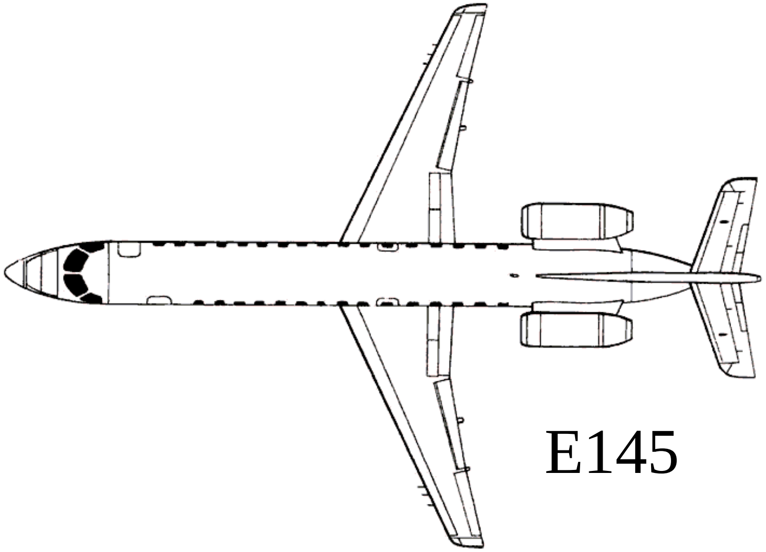
Engine location has its trade-offs

Wing-mounted engines



A320

Fuselage-mounted engines



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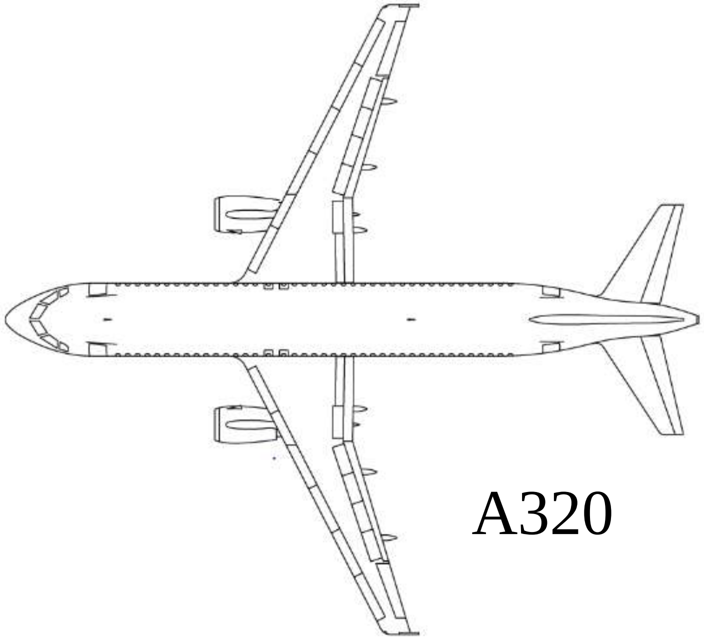
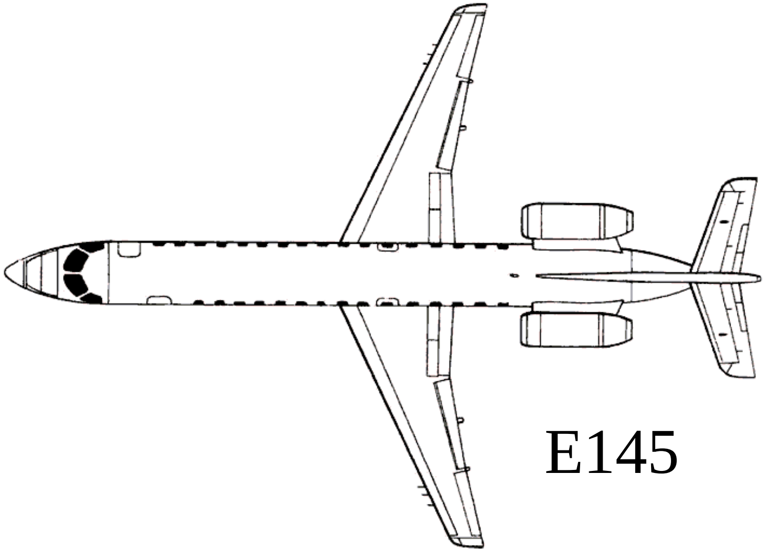
Engine location has its trade-offs

Wing-mounted engines



- Wing load alleviation
- Closer to fuel tanks
- Easier access
- FOD ingestion
- Taller landing gear

Fuselage-mounted engines



- Lower cabin noise
- Smaller yaw moment arm
- Better ground clearance
- Increases fuselage weight
- Brings CG to the rear

Buried engines

De Havilland Comet

wikipedia.org

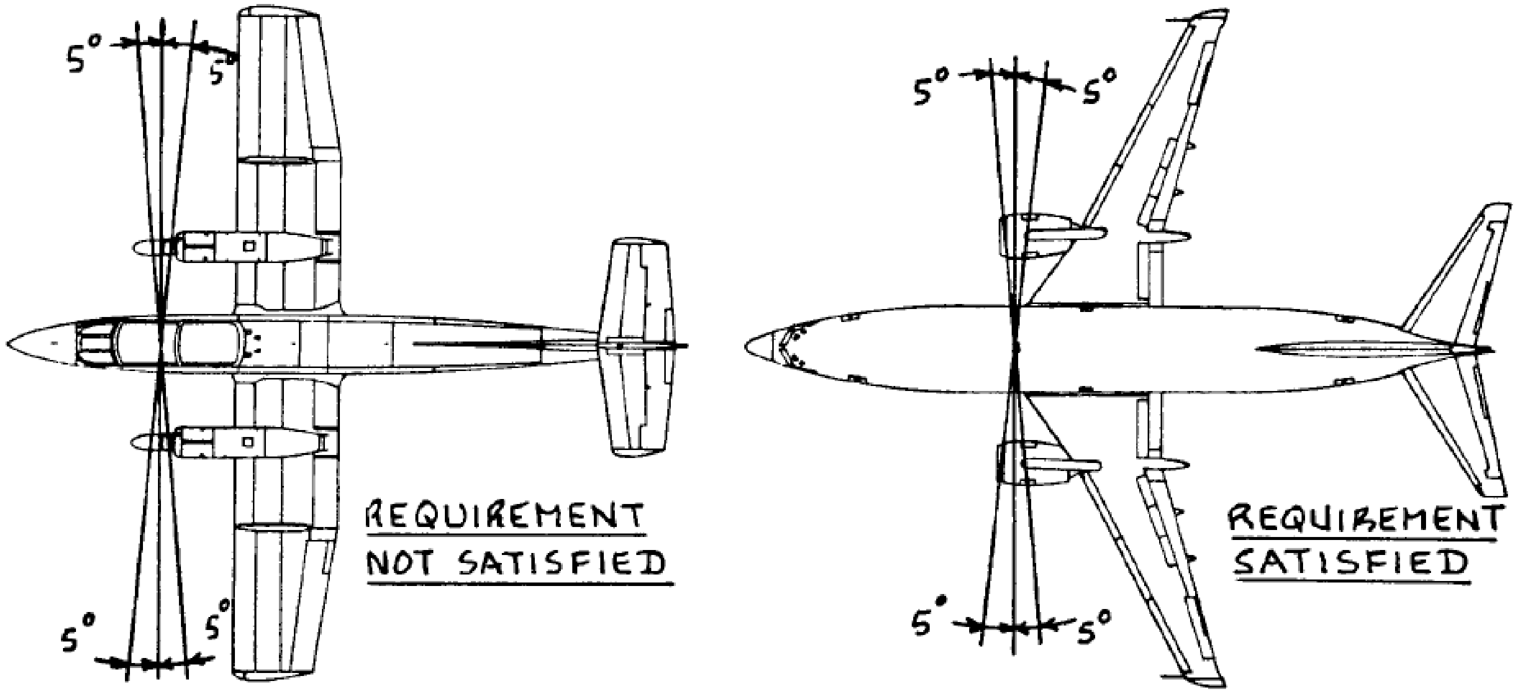
The engine intake should be carefully placed

F-16 – Ventral intake

F-5 – Lateral intake

wikipedia.org

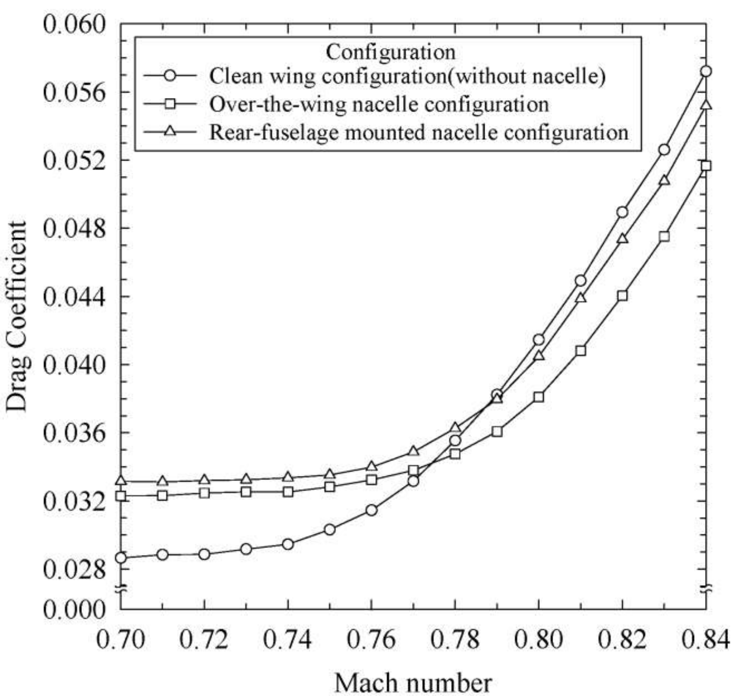
Engine failure cannot compromise critical systems



Unconventional engine mounts

HondaJet

www.forbes.com.br



Fujino, 2005
https://doi.org/10.2514/1.12268

Unconventional engine mounts

www.wikipedia.org

Antonov-72

The engine can enhance maneuverability

F-22

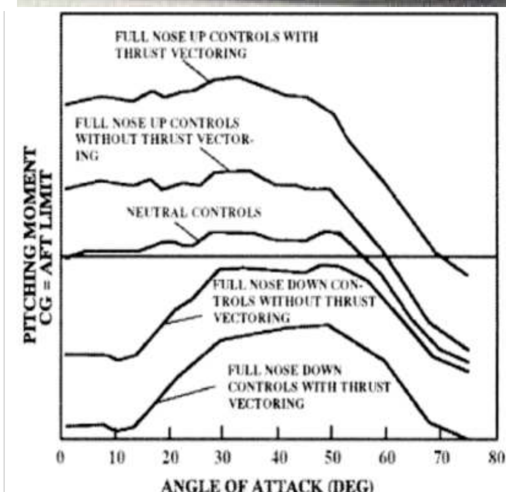


Figure 8. Pitching Moment vs. Angle of Attack

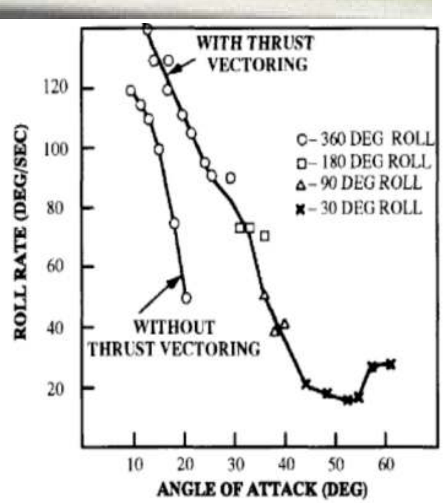


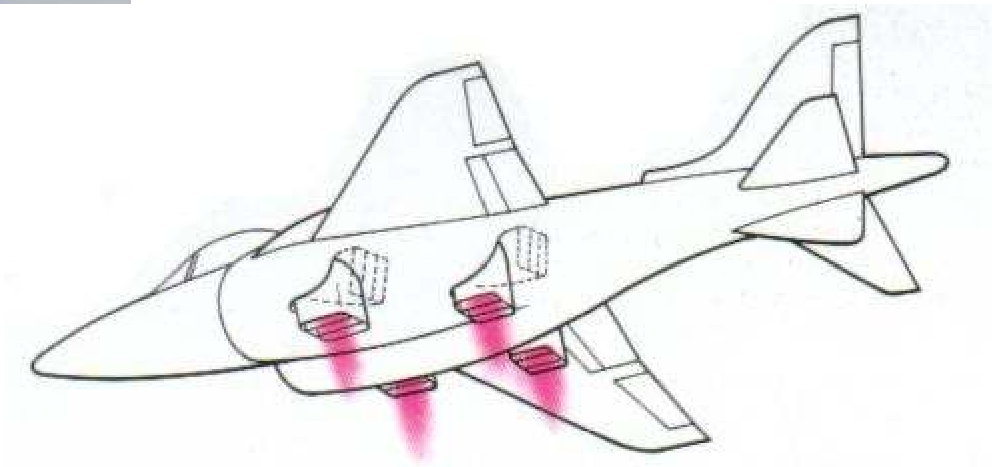
Figure 12. YF–22 Roll Rate vs. Angle of Attack

AIAA 2015-832

The engine can enhance maneuverability

Harrier

wikipedia.org



"Four-poster" thrust-vectoring system

Novel propulsion concepts

STARC-ABL

https://sacd.larc.nasa.gov/asab/asab-projects-2/starc-abl/

Regular turbofans provide power for an electric fan that ingest the boundary layer at the rear of the fuselage

Novel propulsion concepts

Aurora D8

aviationweek.com

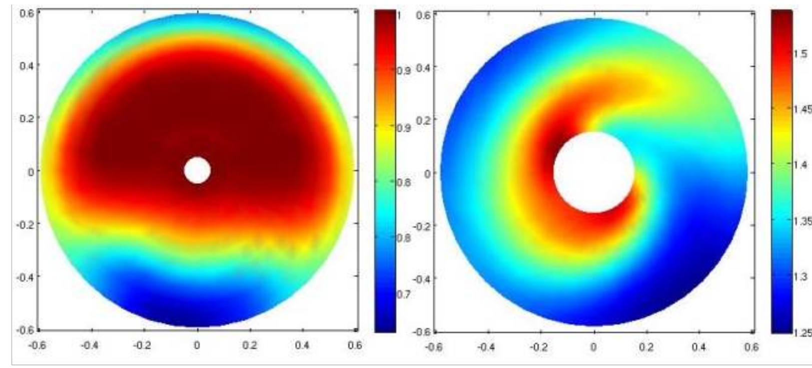


Figure 7. Stagnation pressure distortion transfer calculated from body force analysis.

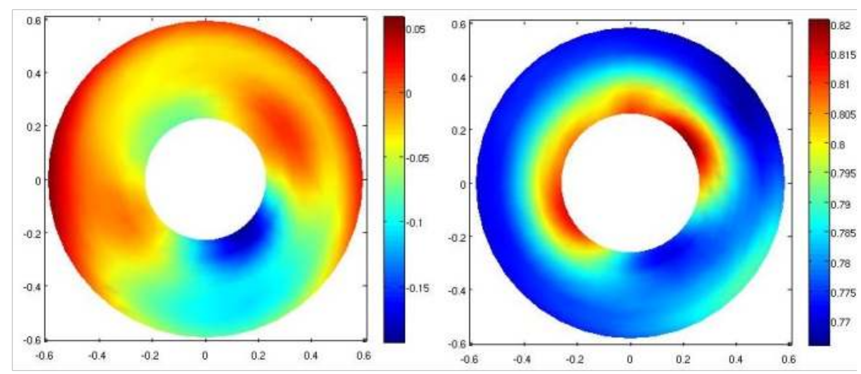


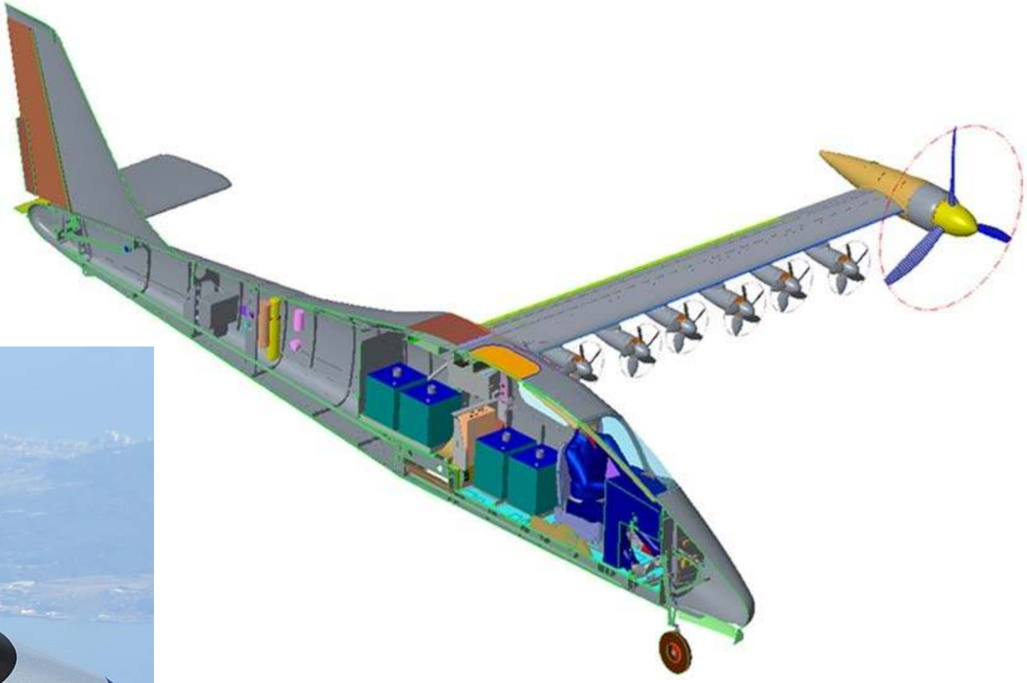
Figure 8. Static pressure distribution upstream and downstream of the fan calculated from body force analysis.

BLI – Boundary Layer Ingestion

AIAA 2007-450

Novel propulsion concepts

X-57 Maxwell



wikipedia.org

Distributed electric propulsion

Definição do sistema propulsivo no projeto conceitual

- Selecionar o tipo de motor com base nos requisitos de missão (ex: velocidade e altitude de cruzeiro)

- Obter ou estimar o consumo específico e o peso do motor para alimentar estimativas de peso e desempenho

- Selecionar o motor com base na tração requerida pela análise de desempenho (Será utilizado um motor “off the shelf” ou um novo motor será desenvolvido?)

- Definir o local de instalação do motor e como será o airframe ao seu redor

Roteiro

- Propulsão
- Peso

O peso de uma aeronave pode ser subdividido em componentes

$$W_0 = W_p + W_c + W_f + W_e$$

Maximum Takeoff Weight

- Peso máximo no qual a aeronave pode cumprir os requisitos dos clientes e dos homologadores

- Determina qual regulamento rege a aeronave (FAR 23 ou FAR 25)

- Define taxas aeroportuárias

- Diversas regressões, como estimativas de custos de operação e pesos de componentes, baseiam-se no MTOW

- Aerodinâmica, propulsão e desempenho determinam esse valor

O peso de uma aeronave pode ser subdividido em componentes

$$W_0 = W_p + W_c + W_f + W_e$$

Payload Weight

- Peso da carga paga determinada pelo cliente ou pelos requisitos de missão

TABLE 2-1. STANDARD AVERAGE PASSENGER WEIGHTS

Standard Average Passenger Weight	Weight Per Passenger
Summer Weights	
Average adult passenger weight	190 lb
Average adult male passenger weight	200 lb
Average adult female passenger weight	179 lb
Child weight (2 years to less than 13 years of age)	82 lb
Winter Weights	
Average adult passenger weight	195 lb
Average adult male passenger weight	205 lb
Average adult female passenger weight	184 lb
Child weight (2 years to less than 13 years of age)	87 lb

Já inclui bagagem

FAA AC 120-27E

O peso de uma aeronave pode ser subdividido em componentes

$$W_0 = W_p + W_c + W_f + W_e$$

Crew Weight

- Peso da tripulação

TABLE 2-3. STANDARD CREWMEMBER WEIGHTS

Crewmember	Average Weight	Average Weight with Bags
Flight crewmember	190 lb	240 lb
Flight attendant	170 lb	210 lb
Male flight attendant	180 lb	220 lb
Female flight attendant	160 lb	200 lb
Crewmember roller bag	30 lb	NA
Pilot flight bag	20 lb	NA
Flight attendant kit	10 lb	NA

FAA AC 120-27E

O peso de uma aeronave pode ser subdividido em componentes

$$W_0 = W_p + W_c + W_f + W_e$$

Crew Weight

FAR 121.391

Mais de 7500 lbs de carga paga:

- Entre 10 e 50 passageiros: 1 atendente

Menos de 7500 lbs de carga paga:

- Entre 20 e 50 passageiros: 1 atendente

Para todas as aeronaves:

- Entre 51 e 100 passageiros: 2 atendentes
- Mais de 100 passageiros: 1 atendente para cada grupo de 50 passageiros

O peso de uma aeronave pode ser subdividido em componentes

$$W_0 = W_p + W_c + W_f + W_e$$

Fuel Weight

- O peso de combustível é calculado por frações de pesos levando em conta a missão

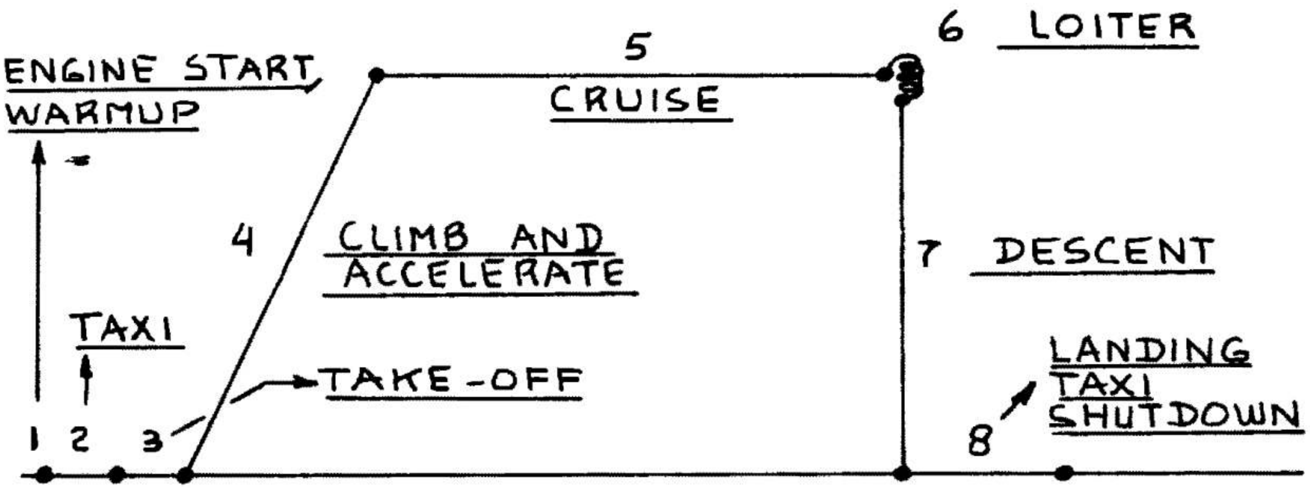


Figure 2.1 Mission Profile for an Arbitrary Airplane

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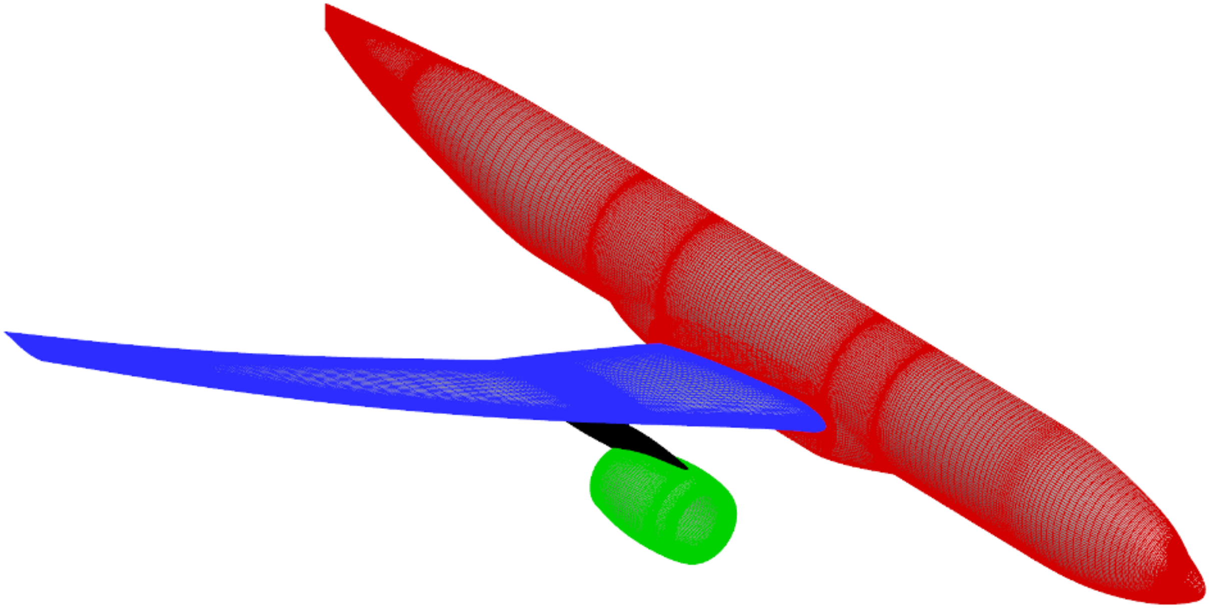
O peso de uma aeronave pode ser subdividido em componentes

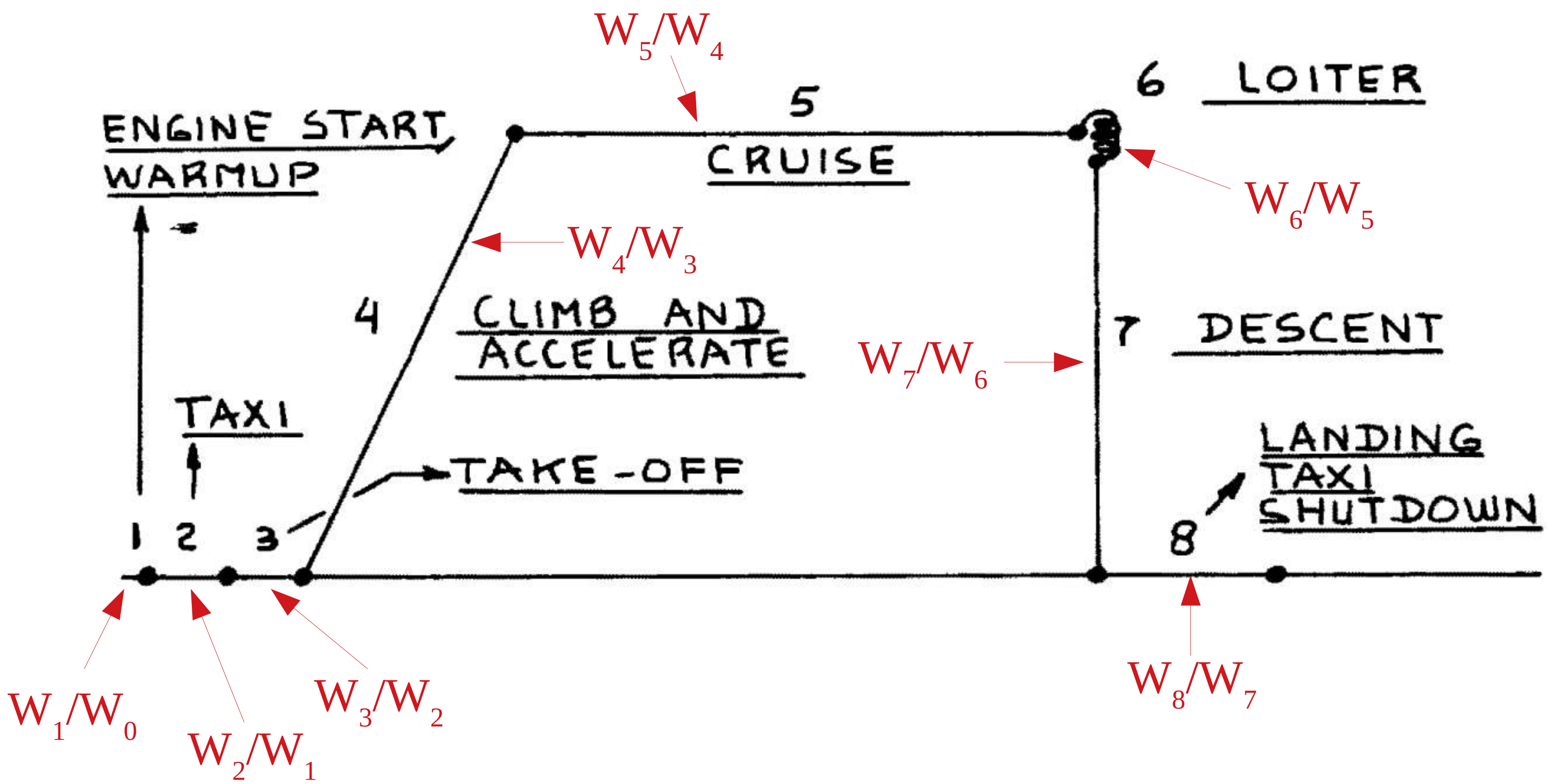
$$W_0 = W_p + W_c + W_f + W_e$$

Empty Weight

- O peso vazio pode ser calculado por meio da análise de componentes da aeronave



Analisamos frações de redução de peso para estimar o peso total de combustível



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Algumas frações de peso podem ser obtidas a partir de dados históricos

Table 2.1 Suggested Fuel-Fractions For Several Mission Phases

Mission Phase No. (See Fig.2.1) Airplane Type:	Engine Start, Warm-up 1	Taxi 2	Take-off 3	Climb 4	Descent 7	Landing Taxi, Shutdown 8
1. Homebuilt	0.998	0.998	0.998	0.995	0.995	0.995
2. Single Engine	0.995	0.997	0.998	0.992	0.993	0.993
3. Twin Engine	0.992	0.996	0.996	0.990	0.992	0.992
4. Agricultural	0.996	0.995	0.996	0.998	0.999	0.998
5. Business Jets	0.990	0.995	0.995	0.980	0.990	0.992
6. Regional TBP's	0.990	0.995	0.995	0.985	0.985	0.995
7. Transport Jets	0.990	0.990	0.995	0.980	0.990	0.992
8. Military Trainers	0.990	0.990	0.990	0.980	0.990	0.995
9. Fighters	0.990	0.990	0.990	0.96-0.90	0.990	0.995
10. Mil.Patrol, Bomb, Transport	0.990	0.990	0.995	0.980	0.990	0.992
11. Flying Boats, Amphibious, Float Airplanes	0.992	0.990	0.996	0.985	0.990	0.990
12. Supersonic Cruise	0.990	0.995	0.995	0.92-0.87	0.985	0.992

Notes: 1. The numbers in this table are based on experience or on judgment.
2. There is no substitute for common sense! If and when common sense so dictates, the reader should substitute other values for the fractions suggested in this table.

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Outras razões podem ser estimadas por meio das Equações de Breguet

- Tempo

$$\frac{W_{final}}{W_{inicial}} = \exp\left(-\frac{C \cdot E}{L/D}\right)$$

- Alcance

$$\frac{W_{final}}{W_{inicial}} = \exp\left(-\frac{C \cdot R}{V \cdot L/D}\right)$$

O consumo específico depende do tipo de motor

Raymer

Table 3.3 Specific Fuel Consumption, C

Typical jet SFCs: 1/hr {mg/Ns}	Cruise	Loiter
Pure turbojet	0.9 {25.5}	0.8 {22.7}
Low-bypass turbofan	0.8 {22.7}	0.7 {19.8}
High-bypass turbofan	0.5 {14.1}	0.4 {11.3}

Table 3.4 Propeller-Specific Fuel Consumption, C_{bhp}

Propeller: $C = C_{power}\, V/\eta_p = C_{bhp}\, V/(550\eta_p)$ Typical C_{bhp}: lb/hr/bhp {mg/W-s}	Cruise	Loiter
Piston-prop (fixed pitch)	0.4 {0.068}	0.5 {0.085}
Piston-prop (variable pitch)	0.4 {0.068}	0.5 {0.085}
Turboprop	0.5 {0.085}	0.6 {0.101}

Conversão de PSFC para TSFC

$$\mathrm{TSFC} = \frac{V}{\eta_p} \cdot \mathrm{PSFC}$$

Estimativas de eficiência aerodinâmica

Table 2.2 Suggested Values For L/D, c_j, η_p, And For c_p For Several Mission Phases

Mission Phase No. (See Fig. 2.1)	Cruise (5) L/D	Cruise (5) c_j lbs/lbs/hr	Cruise (5) c_p lbs/hp/hr	Cruise (5) η_p	Loiter (6) L/D	Loiter (6) c_j lbs/lbs/hr	Loiter (6) c_p lbs/hp/hr	Loiter (6) η_p
Airplane Type								
1. Homebuilt	8-10•		0.6-0.8	0.7	10-12		0.5-0.7	0.6
2. Single Engine	8-10		0.5-0.7	0.8	10-12		0.5-0.7	0.7
3. Twin Engine	8-10		0.5-0.7	0.82	9-11		0.5-0.7	0.72
4. Agricultural	5-7		0.5-0.7	0.82	8-10		0.5-0.7	0.72
5. Business Jets	10-12	0.5-0.9			12-14	0.4-0.6		
6. Regional TBP's	11-13		0.4-0.6	0.85	14-16		0.5-0.7	0.77
7. Transport Jets	13-15	0.5-0.9			14-18	0.4-0.6		
8. Military Trainers	8-10	0.5-1.0	0.4-0.6	0.82	10-14	0.4-0.6	0.5-0.7	0.77
9. Fighters	4-7	0.6-1.4	0.5-0.7	0.82	6-9	0.6-0.8	0.5-0.7	0.77
10. Mil.Patrol, Bomb, Transport	13-15	0.5-0.9	0.4-0.7	0.82	14-18	0.4-0.6	0.5-0.7	0.77
11. Flying Boats, Amphibious, Float Airplanes	10-12	0.5-0.9	0.5-0.7	0.82	13-15	0.4-0.6	0.5-0.7	0.77
12. Supersonic Cruise	4-6	0.7-1.5			7-9	0.6-0.8		

Notes:
1. The numbers in this table represent ranges based on existing engines.
2. There is no substitute for common sense! If and when actual data are available, these should be used.
3. A good estimate for L/D can be made with the drag polar method of Sub-section 3.4.1.

• Homebuilts with smooth exteriors and/or high wing loadings can have L/D values which are considerably higher.

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Aeronaves atuais conseguem atingir L/D maiores

Reservas de combustível

- FAR 125.377
  - Voos domésticos: Loiter de 45 minutos e aeroporto alternativo
  - Voos internacionais: Loiter de 10% do tempo original da missão + aeroporto alternativo + 30 minutos de loiter

- Air Transportation Agency (ATA) recomenda:
  - Aeroporto alternativo em 200 milhas náuticas

O peso vazio pode ser estimado por regressões históricas

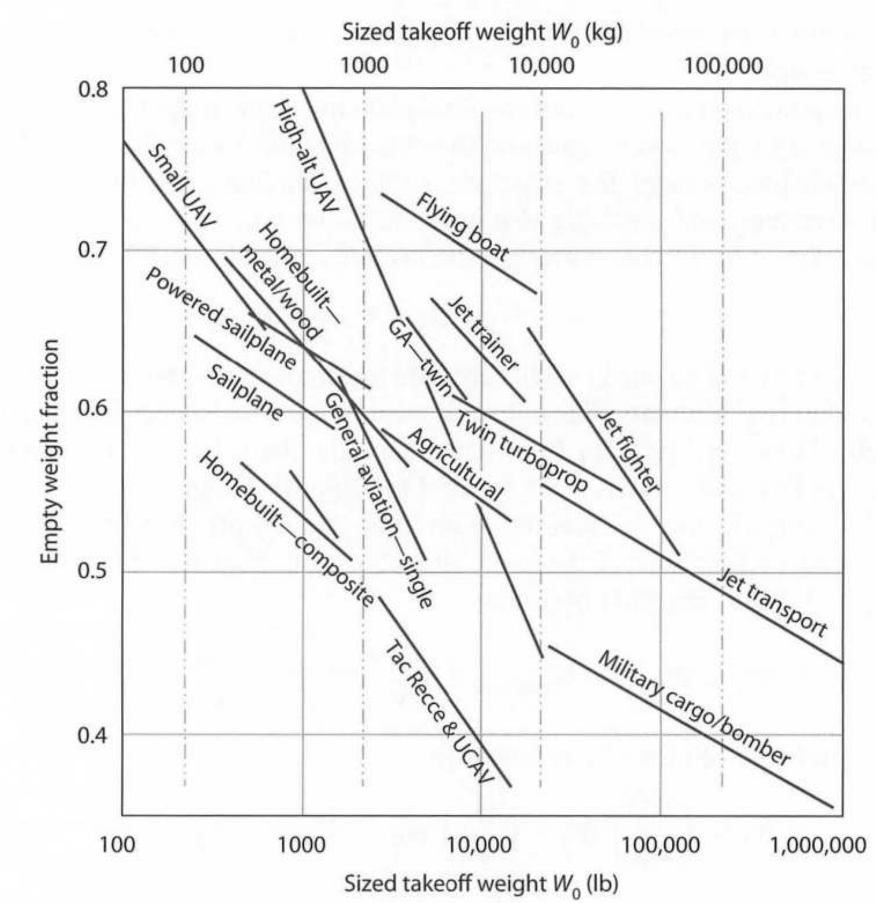

Table 3.1 Empty Weight Fraction vs W_0

$W_e/W_0 = AW_0^C K_{vs}$	A	{A-metric}	C
Sailplane—unpowered	0.86	{0.83}	−0.05
Sailplane—powered	0.91	{0.88}	−0.05
Homebuilt—metal/wood	1.19	{1.11}	−0.09
Homebuilt—composite	1.15	{1.07}	−0.09
General aviation—single engine	2.36	{2.05}	−0.18
General aviation—twin engine	1.51	{1.4}	−0.10
Agricultural aircraft	0.74	{0.72}	−0.03
Twin turboprop	0.96	{0.92}	−0.05
Flying boat	1.09	{1.05}	−0.05
Jet trainer	1.59	{1.47}	−0.10
Jet fighter	2.34	{2.11}	−0.13
Military cargo/bomber	0.93	{0.88}	−0.07
Jet transport	1.02	{0.97}	−0.06
UAV—Tac Recce & UCAV	1.67	{1.53}	−0.16
UAV—high altitude	2.75	{2.48}	−0.18
UAV—small	0.97	{0.86}	−0.06

K_{vs} = variable sweep constant = 1.04 if variable sweep = 1.00 if fixed sweep

Raymer

Podemos aprimorar a estimativa do peso vazio considerando contribuições por componente

Table 15.2 Approximate Empty Weight Buildup

	Fighters		Transport & Bomber		General aviation		Multiplier	Approximate location
	lb/ft^2	kg/m^2	lb/ft^2	kg/m^2	lb/ft^2	kg/m^2		
Wing	9	44	10	49	2.5	12	$S_{\text{exposed planform}}$	40% MAC
Horizontal tail	4	20	5.5	27	2	10	$S_{\text{exposed planform}}$	40% MAC
Vertical tail	5.3	26	5.5	27	2	10	$S_{\text{exposed planform}}$	40% MAC
Fuselage	4.8	23	5	24	1.4	7	$S_{\text{wetted area}}$	40–50% length
	Weight ratio		Weight ratio		Weight ratio			
Landing gear*	0.033		0.043		0.057		TOGW	centroid
Landing gear—Navy	0.045		—		—		TOGW	centroid
Installed engine	1.3		1.3		1.4		Engine weight	centroid
"All-else empty"	0.17		0.17		0.1		TOGW	40–50% length

*15% to nose gear, 85% to main gear; reduce gear weight by 0.014 W_0 if fixed gear.

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Fórmulas mais complexas permitem um melhor estudo de soluções de compromisso

15.3.2 Cargo/Transport Weights (British Units, Results in Pounds)

$$W_{\text{wing}} = 0.0051(W_{\text{dg}}N_z)^{0.557}S_w^{0.649}A^{0.5}(t/c)_{\text{root}}^{-0.4}(1+\lambda)^{0.1} \times (\cos\Lambda)^{-1.0}S_{\text{csw}}^{0.1} \tag{15.25}$$

$$W_{\text{horizontal tail}} = 0.0379K_{\text{uht}}(1+F_w/B_h)^{-0.25}W_{\text{dg}}^{0.639}N_z^{0.10} \times S_{\text{ht}}^{0.75}L_t^{-1.0}K_y^{0.704}(\cos\Lambda_{\text{ht}})^{-1.0} \times A_h^{0.166}(1+S_e/S_{\text{ht}})^{0.1} \tag{15.26}$$

$$W_{\text{vertical tail}} = 0.0026(1+H_t/H_v)^{0.225}W_{\text{dg}}^{0.556}N_z^{0.536}L_t^{-0.5} \times S_{\text{vt}}^{0.5}K_z^{0.875}(\cos\Lambda_{\text{vt}})^{-1}A_v^{0.35}(t/c)_{\text{root}}^{-0.5} \tag{15.27}$$

$$W_{\text{fuselage}} = 0.3280K_{\text{door}}K_{\text{Lg}}(W_{\text{dg}}N_z)^{0.5}L^{0.25}S_f^{0.302} \times (1+K_{\text{ws}})^{0.04}(L/D)^{0.10} \tag{15.28}$$

where $K_{\text{ws}} = 0.75\,[(1+2\lambda)/(1+\lambda)]\,(B_w \tan\Lambda/L)$ to correct for effects of wing geometry on fuselage weight.

$$W_{\text{main landing gear}} = 0.0106\,K_{\text{mp}}W_l^{0.888}N_l^{0.25}L_m^{0.4}N_{\text{mw}}^{0.321}N_{\text{mss}}^{-0.5}V_{\text{stall}}^{0.1} \tag{15.29}$$

$$W_{\text{nose landing gear}} = 0.032K_{\text{np}}W_l^{0.646}N_l^{0.2}L_n^{0.5}N_{\text{nw}}^{0.45} \tag{15.30}$$

$$W_{\text{nacelle group}} = 0.6724K_{\text{ng}}N_{\text{Lt}}^{0.10}N_w^{0.294}N_z^{0.119}W_{\text{ec}}^{0.611} \times N_{\text{en}}^{0.984}S_n^{0.224}$$

(includes air induction and pylon) (15.31)

$$W_{\text{engine controls}} = 5.0N_{\text{en}} + 0.80L_{\text{ec}} \tag{15.32}$$

$$W_{\text{starter (pneumatic)}} = 49.19\left(\frac{N_{\text{en}}W_{\text{en}}}{1000}\right)^{0.541} \tag{15.33}$$

$$W_{\text{fuel system}} = 2.405V_t^{0.606}(1+V_i/V_t)^{-1.0}(1+V_p/V_t)N_t^{0.5} \tag{15.34}$$

$$W_{\text{flight controls}} = 145.9N_f^{0.554}(1+N_m/N_f)^{-1.0} \times S_{\text{cs}}^{0.20}(I_{\text{yaw}}\times 10^{-6})^{0.07} \tag{15.35}$$

$$W_{\text{APU installed}} = 2.2W_{\text{APU uninstalled}} \tag{15.36}$$

$$W_{\text{instruments}} = 4.509K_rK_{\text{tp}}N_c^{0.541}N_{\text{en}}(L_f+B_w)^{0.5} \tag{15.37}$$

$$W_{\text{hydraulics}} = 0.2673N_f(L_f+B_w)^{0.937} \tag{15.38}$$

$$W_{\text{electrical}} = 7.291R_{\text{kva}}^{0.782}L_a^{0.346}N_{\text{gen}}^{0.10} \tag{15.39}$$

$$W_{\text{avionics}} = 1.73W_{\text{uav}}^{0.983} \tag{15.40}$$

$$W_{\text{furnishings}} = 0.0577N_c^{0.1}W_c^{0.393}S_f^{0.75}$$

(does not include cargo handling gear or seats) (15.41)

$$W_{\text{air conditioning}} = 62.36N_p^{0.25}(V_{\text{pr}}/1000)^{0.604}W_{\text{uav}}^{0.10} \tag{15.42}$$

$$W_{\text{anti-ice}} = 0.002W_{\text{dg}} \tag{15.43}$$

$$W_{\text{handling gear}} = 3.0\times 10^{-4}W_{\text{dg}} \tag{15.44}$$

$$W_{\substack{\text{military cargo}\\ \text{handling system}}} = 2.4\times(\text{cargo floor area, ft}^2) \tag{15.45}$$

Raymer

O peso pode ser calculado por um processo iterativo

(alguma notas estao na apr

comecamos chutando um w0. estima-se wf e we

Atualizar para próxima iteração

$$W_{0,guess}$$

Utilizar o “chute” para calcular as parcelas

$$W_0 = W_p + W_c + W_f + W_e$$

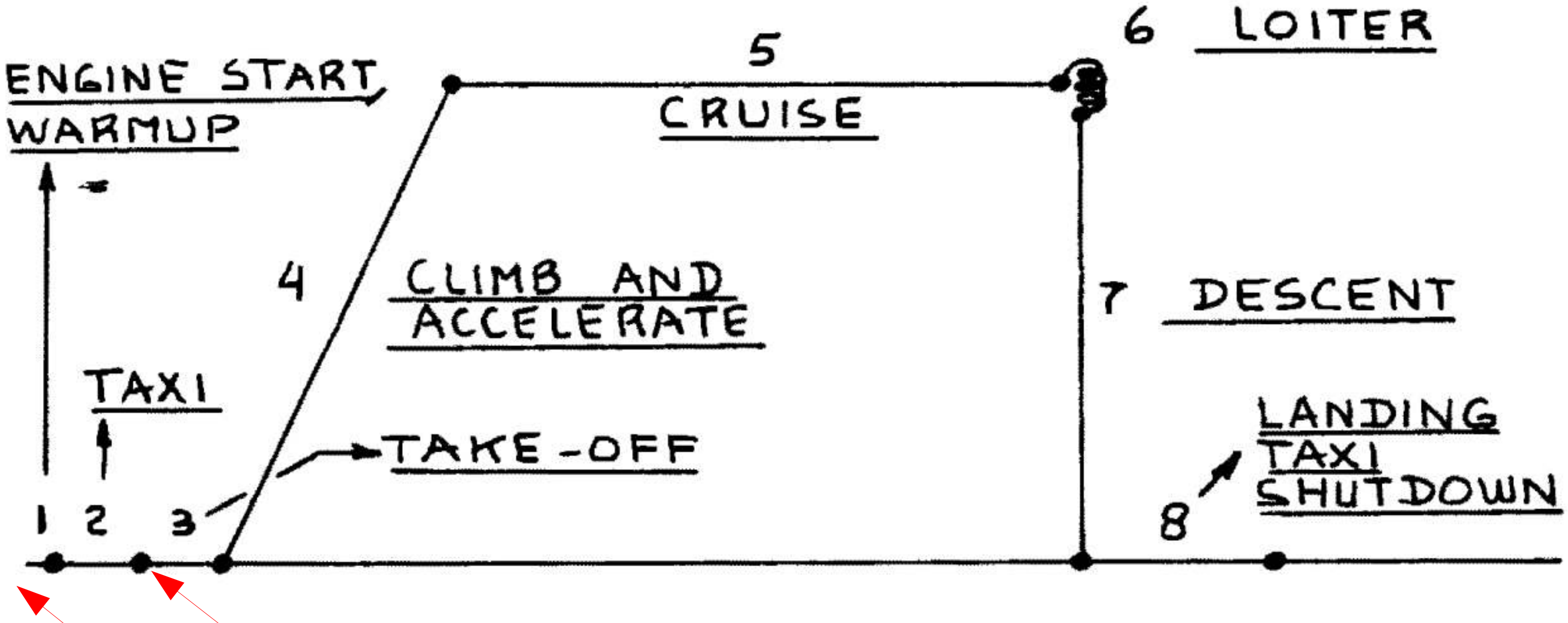
Repetimos o processo até que W_0 e $W_{0,guess}$ fiquem próximos (diferença menor que 100 N, por exemplo)

Definições de peso

- MTOW (Maximum Takeoff Weight)
  - Máximo peso que aeronave pode apresentar no ínicio da decolagem e ainda permita atender requisitos de desempenho e segurança
- MZFW (Maximum Zero Fuel Weight)
  - Máximo peso que a aeronave desabastecida pode ter sem comprometer sua integridade
  - Peso vazio + Tripulação + Máxima carga paga
- BOW (Basic Operating Weight)
  - Peso vazio e tripulação (mínimo para aeronave operar)
- MLW (Maximum Landing Weight)
  - Peso máximo que aeronave foi certificada para pousar

Definições de peso

Roskam



MTOW

Ramp Weight

MTOW desconta combustível usado no startup e taxi

Podemos considerar os dois como sendo iguais para nosso curso

Examples

B737-800

- Range = 5436 km
- We/W0 = 52%
- Wf/W0 = 30%
- W0 = 79 tons

B747-8

- Range = 14320 km
- We/W0 = 49%
- Wf/W0 = 41%
- W0 = 448 tons

Examples

U-2

- Range = 11280 km
- We/W0 = 40%
- Wf/W0 = 50%
- W0 = 18 tons

F-14

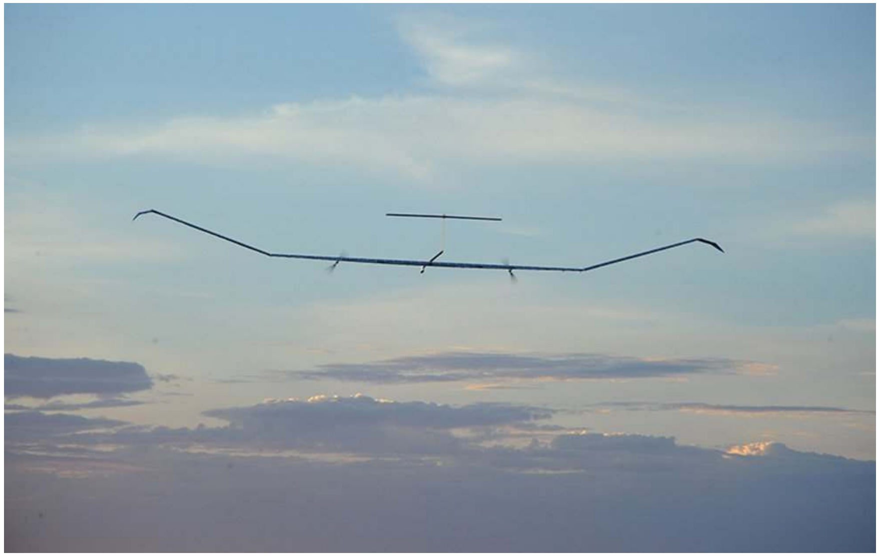
- Range = 3000 km
- We/W0 = 59%
- Wf/W0 = 24%
- W0 = 33 tons

Examples

NASA Helios HP01

- Range = ?
- We/W0 = 65%
- Wf/W0 = 0%
- W0 = 929 kg

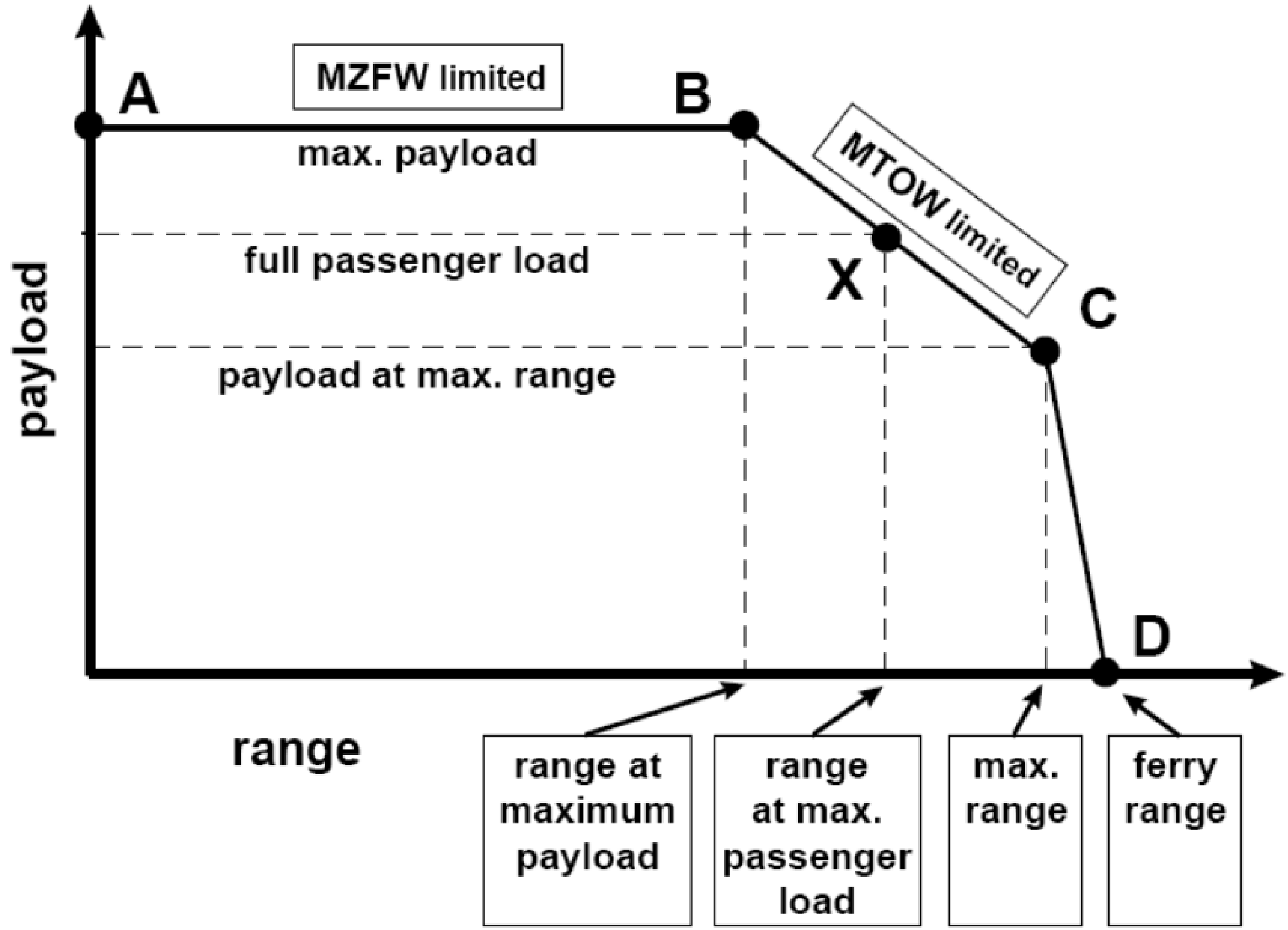
airbus.com



Airbus Zephyr 7

- Range = “Infinite”
- We/W0 = 95%
- Wf/W0 = 0%
- W0 = 53 kg

Payload-Range Diagram



https://www.fzt.haw-hamburg.de/pers/Scholz/HOOU/Aircraft_Design_in_a_Nutshell.pdf

Sensitivity Studies

CASE	MTOW	Wpayload	Wcrew	Wfuel	Wempty
Baseline	45466 kg	9737 kg	455 kg	10633 kg	24641 kg
1kg extra payload	+2,7 kg	+1 kg	+0 kg	+0,5 kg	+1,2 kg

Tarefa

- Implementar códigos das seções 3.3, 3.4, 3.5 e 3.6
- Realizar atividades da seção 3.6.6 e enviar respostas em um PDF até o dia 31/08/2021. O envio deve ser feito para o e-mail ney@ita.br com o título “AP-701 HW04”
- Quiz até o dia 31/08/2021:

  https://forms.gle/HgAPNUDN73anQKZ98